Sea ice multilayer thermodynamics in HadGEM3

Alison McLaren, Martin Best, Helene Hewitt, Jeff Ridley

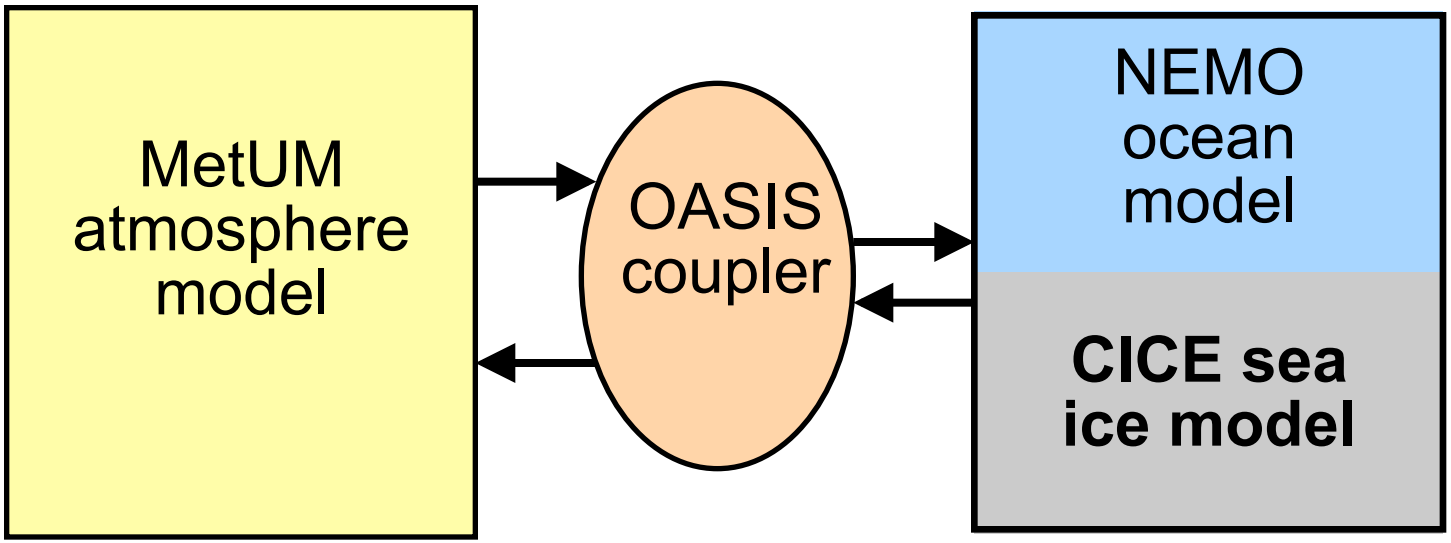
Met Office Hadley Centre

Multilayer thermodynamics in HadGEM3

- Coupled climate model (HadGEM3)
- Current thermodynamics
- Model development – Coupling between the atmosphere and sea ice model
- 1D model tests
- Summary

HadGEM3

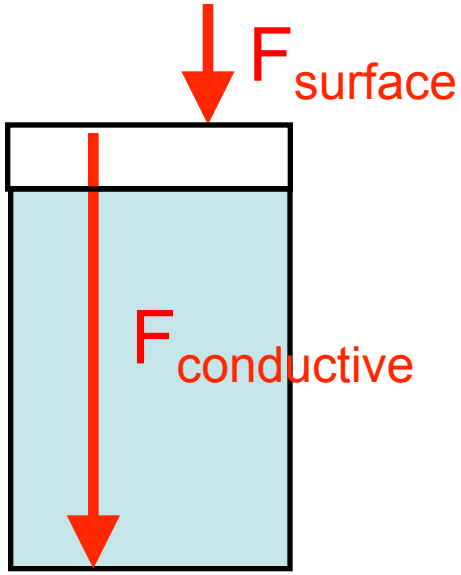
Hadley Centre Global Environmental Model Version 3



- Currently under scientific development
- Sea ice model scientifically very similar to HadGEM1/2 but now use CICE as a separate sub-model
- MetUM uses different grid to NEMO-CICE

Current thermodynamics

- Sea ice thermodynamics partially calculated in atmos model
- Surface fluxes and T are implicitly solved for with overlaying atmos, allowing longer atmos timestep and full diurnal cycle of ice T to be captured.
- Uses ‘zero-layer’ thermodynamics (Semtner, 76) so ignore heat storage - apart from a 10cm surface layer used to capture diurnal cycle
- $F_{surface}$ and $F_{conductive}$ passed to CICE to grow/melt ice
- All dynamics and advection done in CICE



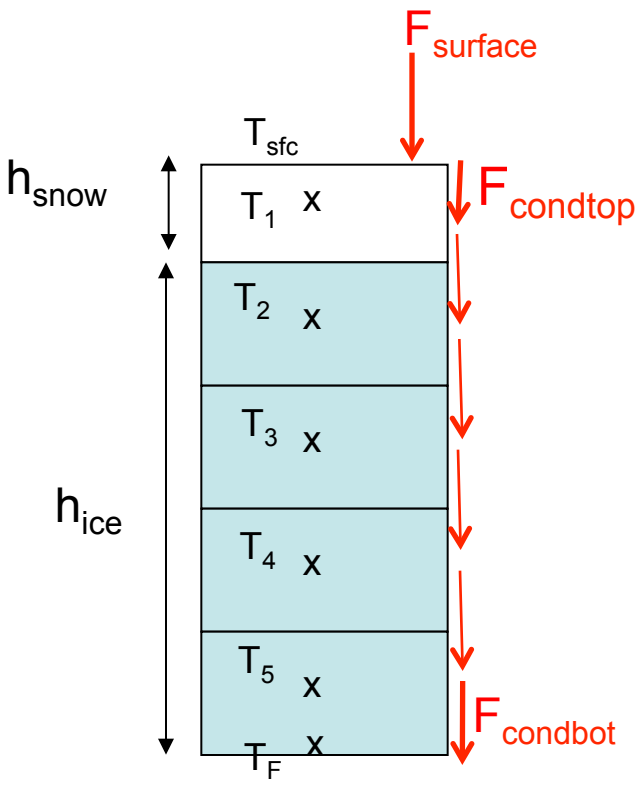
Current thermodynamics

Missing processes related to vertical structure:

- No solar radiation penetrating into ice
- No internal storage of heat / no brine pockets
- Have to include an albedo correction to account for missing penetrating radiation (following Semtner, 76)
- Limits future developments (prognostic salinity, explicit melt ponds)

Multilayer thermodynamics

Where to put the boundary between the atmos and ice model?

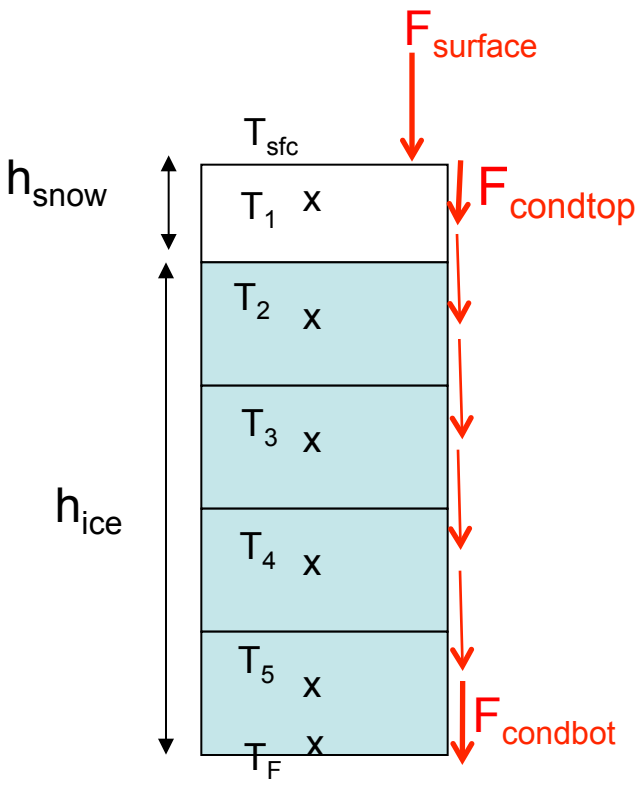


Temperature solver in atmos model?

- Consistent solution through ice and atmos
- Too many coupling fields

Multilayer thermodynamics

Where to put the boundary between the atmos and ice model?

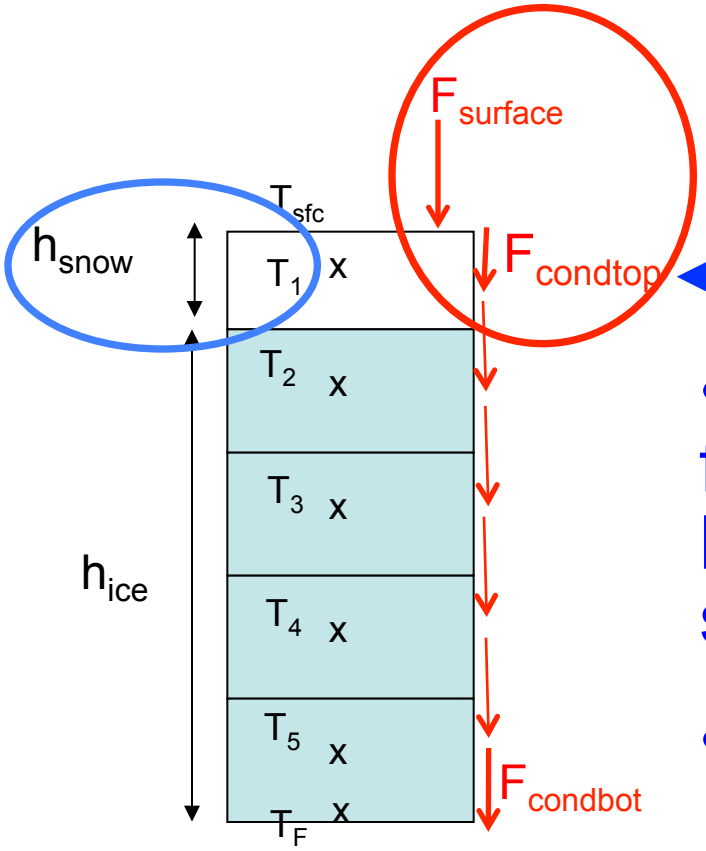


Temperature solver in ice model?

- Standard method in CICE
- Implicit solution throughout ice
- No implicit coupling with overlaying atmosphere
- Major changes to atmos model

Multilayer thermodynamics

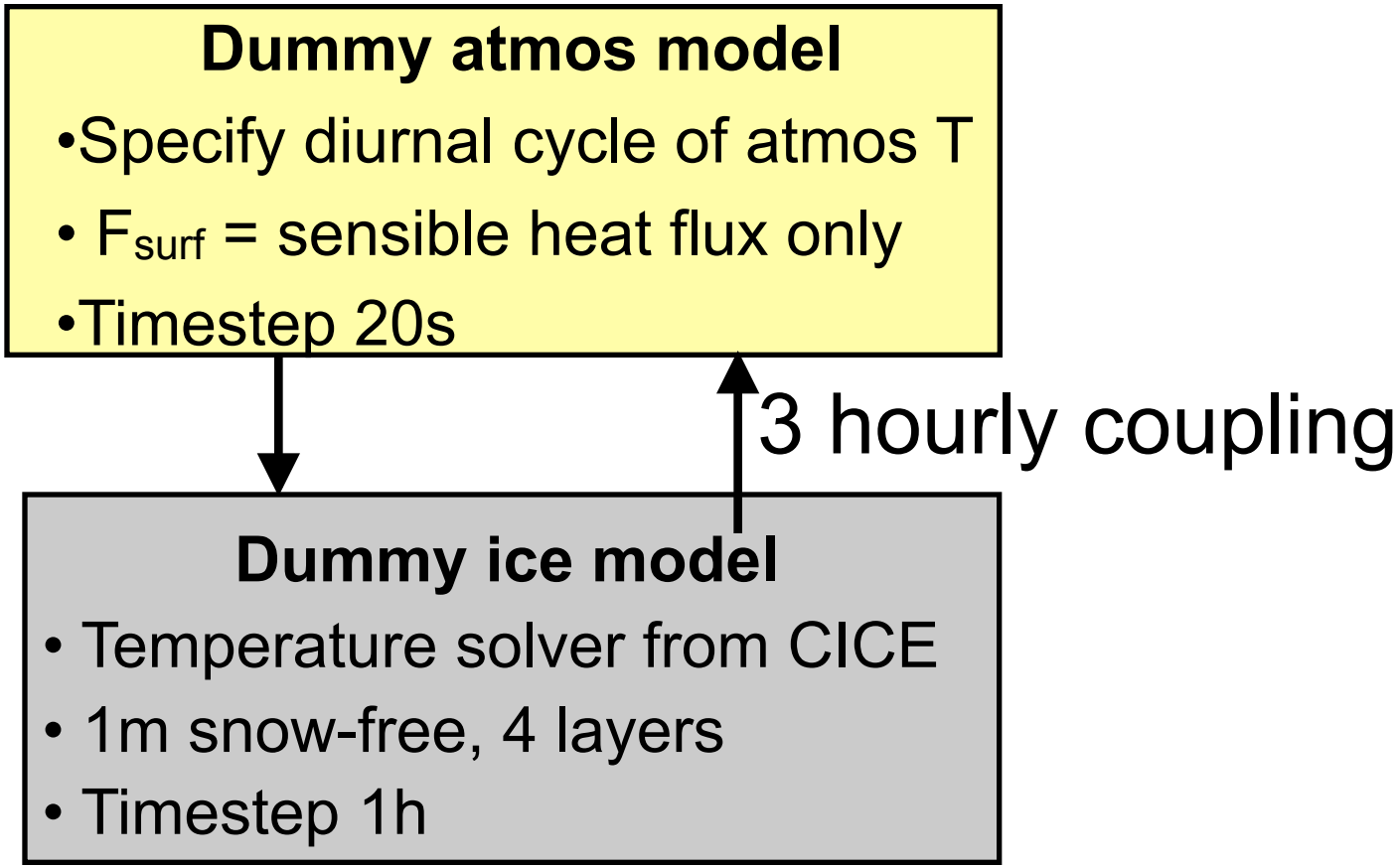
Where to put the boundary between the atmos and ice model?



Temperature solver split between atmos and ice model?

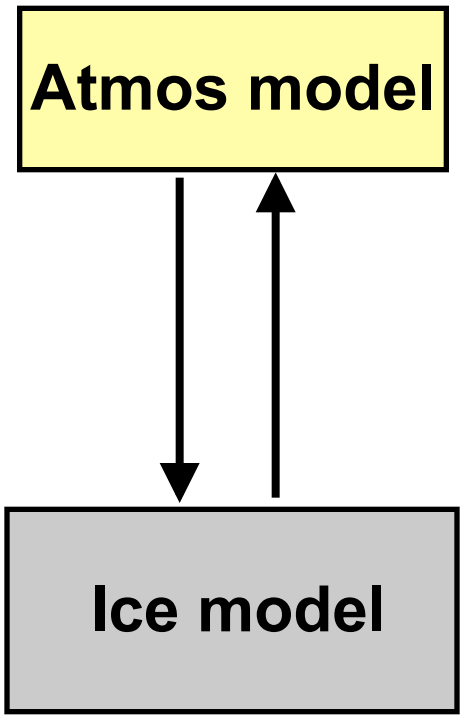
- Timescales: turbulent surface flux < diffusive flux thru ice, so better to solve surface fluxes on shorter atmos model timestep
- Allow longer coupling period
- Consistent with land surface scheme

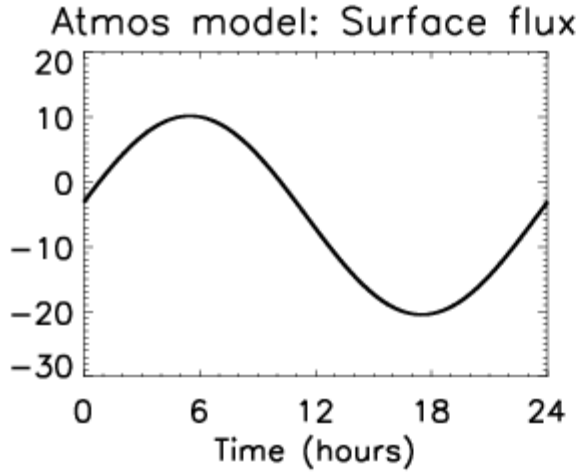
1D model tests – diurnal cycle

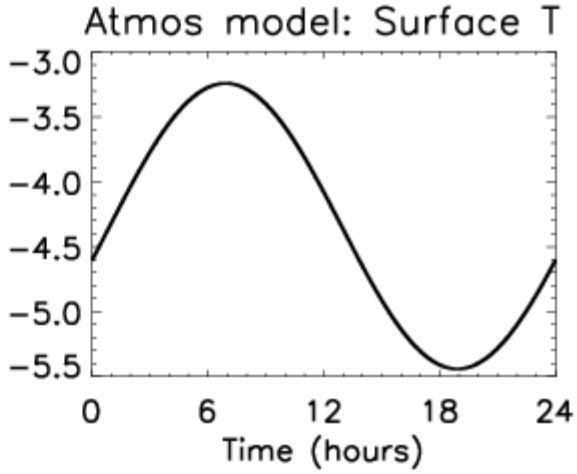


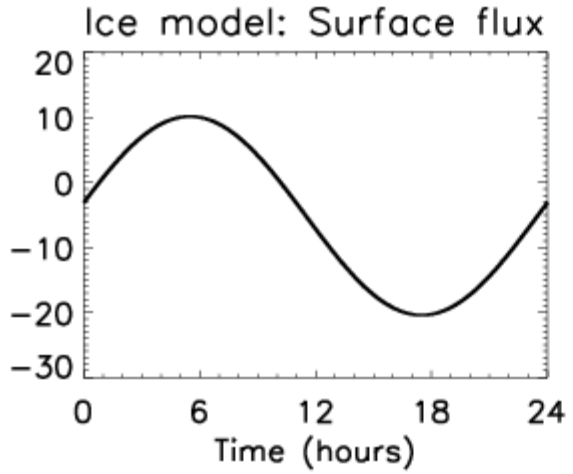
- Test two different coupling approaches
- Compare to high resolution ('Control') run with timestep and coupling frequency = 1s

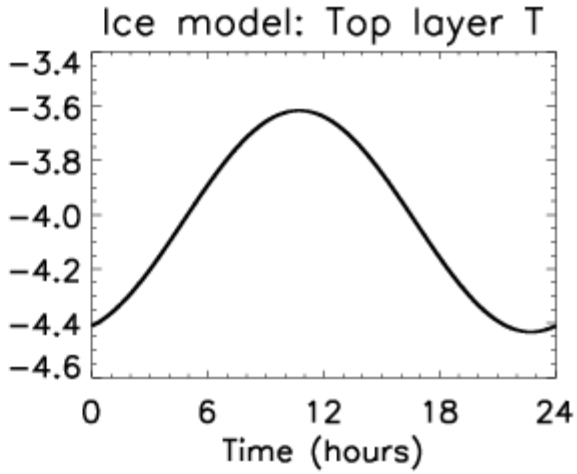
1D model test results





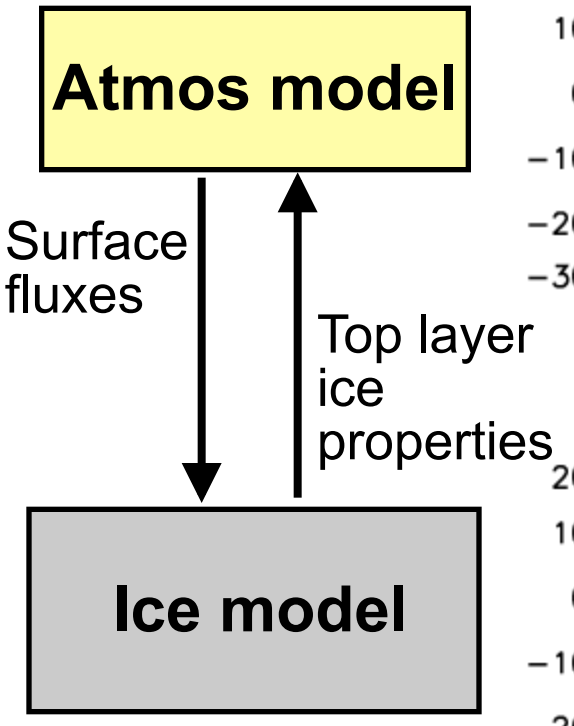


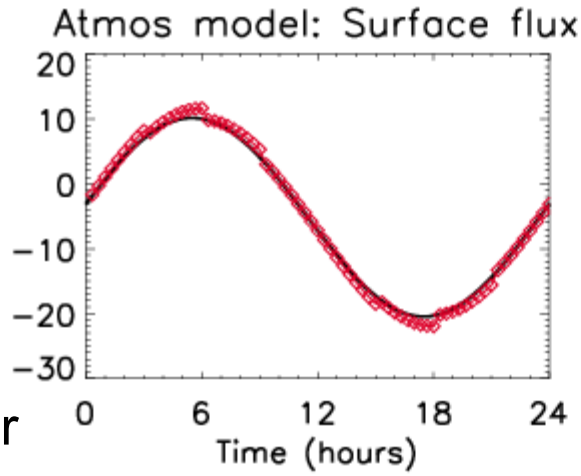


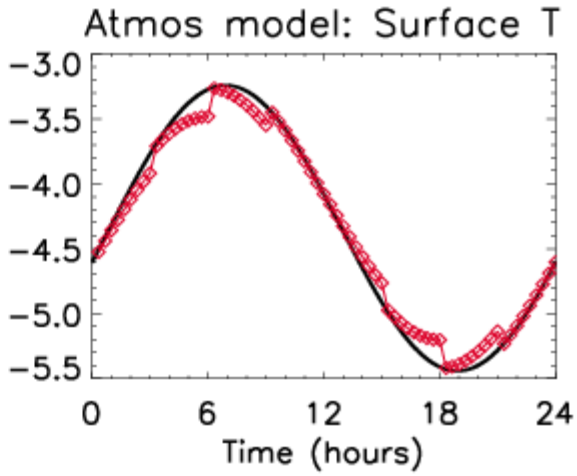


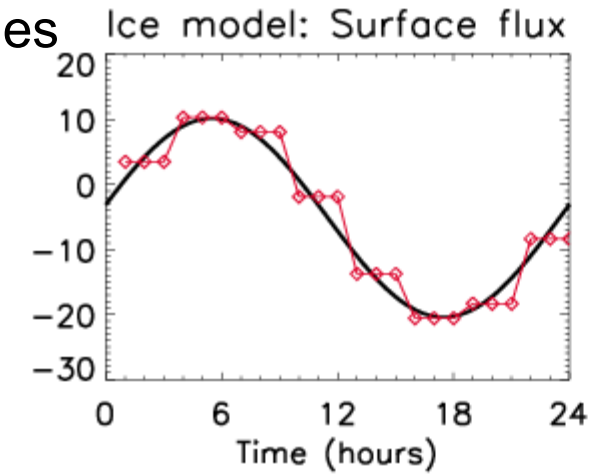
Control

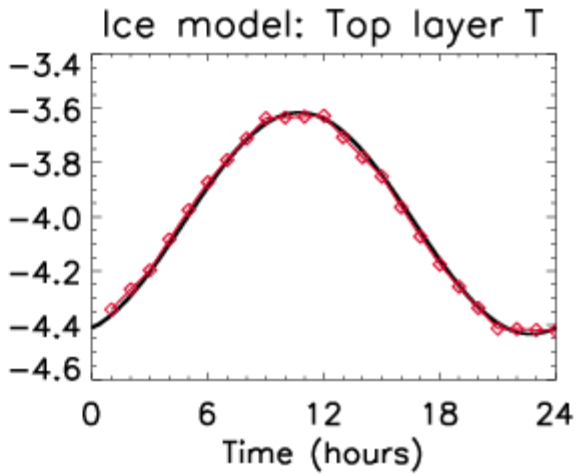
Test results : New coupling





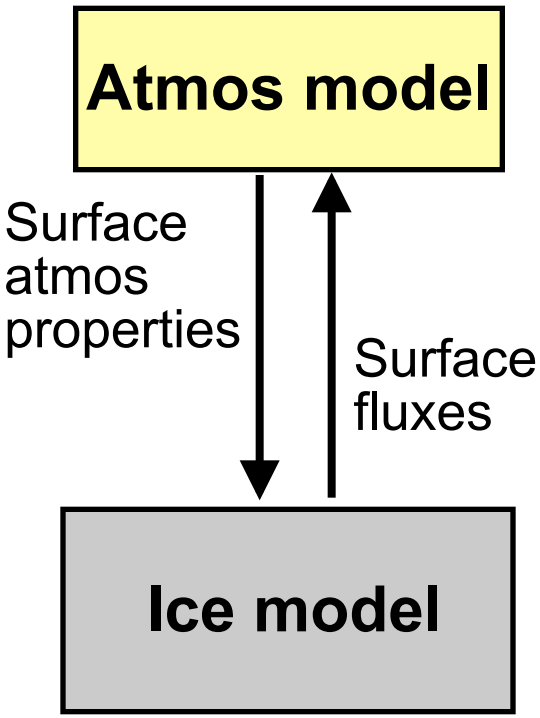


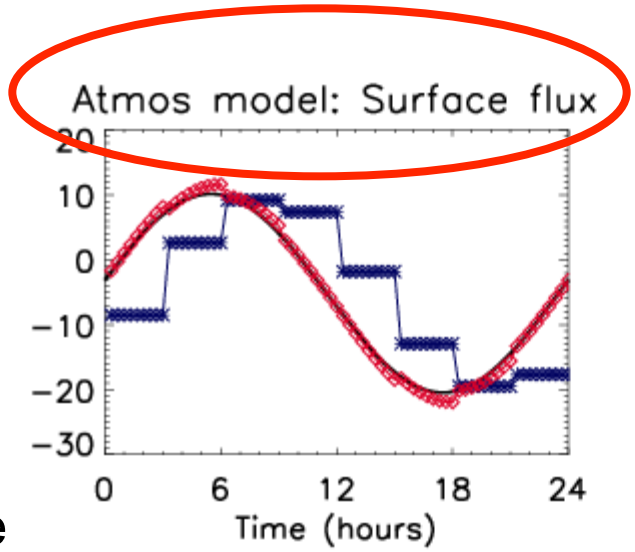


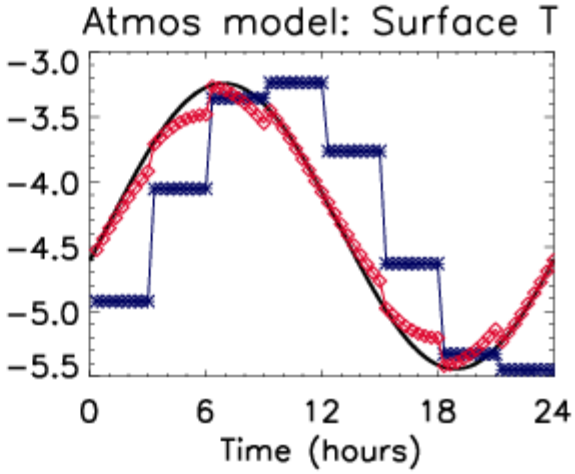


Control New coupling

Test results: Standard coupling







- Differences reduced if use 1 hour coupling (as used in CCSM)
- New coupling method as accurate as standard method
- Vertical resolution is a greater issue

Summary

- Developing multilayer coupling for latest Hadley Centre coupled climate model (HadGEM3)
- Atmos-ice temperature coupling will be in top layer of snow/ice column
- Best location as timescale of diffusive flux through ice > surface turbulent fluxes
- 1D model tests encouraging and show new approach gives more flexibility in coupling frequency
- Still need to investigate the impact of regridding

Current work

- Making code changes now: CICE, NEMO, UM and JULES
- JULES (Joint UK Land Environment Simulator) contains the UM surface exchange scheme so it includes the sea ice surface thermodynamics.
- Also, development will include fully solving surface energy budget on each ice thickness category and using CICE albedo scheme

Importance of diurnal cycle?

- Atmos model at Met Office used for weather forecasting as well
- SHEBA (Beaufort Sea/Chukchi Sea 1997/8):
  - Max diurnal cycle in near-sfc T = 3.3 C
  - Max diurnal cycle in incoming SW = 470 W/m2
- Important for atmosphere model (LW proportional to T^4)
- Less important for ice evolution?
- Good test case for testing coupling in 1D exps.